METHOD FOR MAKING HOT STRIPS OF LIGHTWEIGHT CONSTRUCTION STEEL

Description

**[0001]** The invention relates to a method of making hot strips of a workable lightweight construction steel which in particular can be easily deep-drawn cold, in accordance with the preamble of claim 1.

**[0002]** The hotly contested automobile market forces the manufacturer to continuously look for solutions to lower the consumption of the fleet while retaining highest possible comfort. Weight saving plays hereby a crucial role. To address this desire, the suppliers, especially in the area of the body, use steel of higher strength, without adversely affecting buckling resistance as well as workability to deep-draw and/or stretch-form and the coating.

**[0003]** EP 0 889 144 A1 proposes a solution, using a cold-workable austenitic lightweight construction steel, which in particular can easily be deep-drawn and has a tensile strength of up to 1100 MPa. The main elements of this steel are Si, Al, and Mn in the range of 1 to 6% Si, 1 to 8% Al, and 10 to 30% Mn, the remainder being iron, including common incidental steel elements.

**[0004]** The high deformation degree is realized by TRIP (Transformation Induced Plasticity) and TWIP (Twinning Induced Plasticity) characteristics of the steel. Steels with high Mn content tend to segregate as experienced during conventional extrusion as a result of bending, bulging of the strand, sedimentation, and segregation by suction in the sump peak area.

**[0005]** The macrosegregation, obtained in this way and possibly resulting also in intermetallic phases, causes major strip defects during hot rolling.

[0006] In general, high-alloy steels also have a tendency for internal cracking, which ultimately also represent macrosegregation defects. They are caused, e.g., by bending stress during production.

[0007] The invention is based on the object to provide a method of making hot strips from a workable lightweight construction steel which in particular can be easily deep-drawn cold, to obviate the afore-stated drawbacks.

[0008] According to the teaching of the invention, the steel has contents in mass-% for

C 0.04 to $\leq$ 1.0
Al 0.05 to < 4.0
Si 0.05 to $\leq$ 6.0
Mn 9.0 to $\leq$ 30.0,

the remainder being iron including common incidental steel elements, wherein a melt is cast in a horizontal strip casting unit, close to final dimensions at calm flow and without bending, to form a pre-strip in the range between 6 and 15 mm, and subsequently is fed for further processing. Cr, Cu, Ti, Zr, V, and Nb, may, optionally, be added to the steel melt depending on requirements.

[0009] The steel according to the invention is configured with a structure that is either realized as stabilized $\gamma$ crystal or as part-stabilized $\gamma$ mixed crystal with defined stacking-fault energy, exhibiting a partly multiple TRIP effect.

[0010] The last-mentioned effect is the transformation of a face-centered $\gamma$ mixed crystal into a martensitic $\varepsilon$-structure with closest hexagonal packing of spheres which is then partly transformed into a body-centered $\alpha$-martensite and residual austenite.

$$\gamma_{fcc} \rightarrow \varepsilon \frac{Ms}{hcp} \rightarrow \alpha \frac{Ms}{bcc}$$

fcc = face-centered cubic

bcc = body-centered cubic

hcp = hexagonal closed packed

**[0011]** Numerous tests have shown that the carbon content is crucial for the complex interaction between Al, Si and Mn. It increases the stacking-fault energy on one hand, and expands the metastable austenite range on the other hand. As a consequence, the transformation induced martensitic formation and the thus accompanying solidification is inhibited and the ductility is also increased.

**[0012]** Further improvements can be realized by targeted addition of copper and/or chromium. Addition of copper stabilizes ε-martensite and improves the galvanizing capability. Also chromium stabilizes ε-martensite and improves corrosion resistance.

**[0013]** The advantage of the proposed lightweight construction steel resides in the possibility to cover a broad range of strength and ductility demands by tailoring the alloy composition and selection of process parameter such as deformation degree and heat treatment, allowing tensile strengths of up to 1400 MPa. The addition of carbon plays hereby a key role.

**[0014]** Heretofore, the skilled artisan was of the opinion to reduce the carbon content as far as possible to zero so as to prevent the formation of κ-carbides. This invention overcomes this preconception by proposing a balanced ratio in the addition of aluminum and manganese, thereby allowing also a targeted addition of carbon.

**[0015]** For the phenomenon "delayed fracture" that may be encountered in

steels with predominantly TRIP characteristics, the content of hydrogen in steel plays an important role. The phenomenon manifests itself in the presence of cracks in the edge area of, e.g., deep-drawn cups after a while. The crack formation process may last several days.

**[0016]** For that reason, it is proposed to limit the hydrogen content to < 20 ppm, preferably to < 5 ppm. This can be accomplished through careful treatment during melting, e.g. by a particular rinsing and vacuum treatment.

**[0017]** Depending on requirement, it may be necessary to provide the lightweight construction steel predominantly with TRIP or TWIP characteristics. In a simplest case, this can be implemented by controlling the Mn content. When selecting a lower range of about 9 -18 %, an end product can be expected to have predominantly TRIP characteristics, while a selection of a preferred upper range of about 22 - 30 % results in predominantly TWIP characteristics. As already stated above, this control is possible also by tailoring the addition of other elements, in particular carbon. In this context, it should be noted that as far as sufficient corrosion resistance is concerned, the selection of a higher Cr content for the lower Mn range, and the selection of a lower Cr content for the upper Mn range is advantageous.

**[0018]** To implement the process, it is proposed to realize the flow calmness by employing a conjointly running electromagnetic brake which provides in the ideal situation that the speed of melt feed corresponds to the speed of the revolving conveyor band.

**[0019]** Any detrimental bending during solidification is prevented by supporting the casting band, which receives the underside of the melt, on a plurality of rollers disposed side-by-side. The support is amplified by generating an

underpressure in the area of the casting band so that the casting band is pressed firmly against the rollers.

[0020] In order to maintain these conditions during the critical phase of the solidification, the length of the conveyor band is so selected that the pre-strip is substantially through solidified at the end of the conveyor band before its deflection.

[0021] A homogenization zone follows the end of the conveyor band and is utilized to effect a temperature compensation and possible reduction in tension. This is followed by a further treatment which may involve a direct coiling of the pre-strip or a preceding rolling process to provide the required deformation of at least 50%, preferably of > 70%.

[0022] Direct coiling of the pre-strip has the advantage that the casting speed can be selected to realize optimum conditions for solidification, regardless of the cycle of the following rolling process.

[0023] On the other hand, it may be advantageous in particular for economical reasons (higher productivity) to roll the material according to the invention directly after the casting inline in its entirety or partly to its final thickness.

[0024] When the strand shell is formed at the start of solidification, the strand shell may locally detach from the revolving band of the strip casting unit. This possibly results in inadmissible unevenness on the underside of the pre-strip. To prevent this, it is necessary to ensure as far as possible same cool-down conditions for all surface elements of the forming strand shell of a strip that extends across the width of the conveyor band. This can be attained by conditioning the topside of the revolving band, e.g., through tailored structuring or through application of a thermally insulating separation layer.

**[0025]** One of the afore-mentioned structuring measures involves, e.g., sand blasting or brushing of the topside of the revolving band. An example for a thermally insulating separation layer involves coating through plasma spraying with aluminum oxide or zirconium oxide, for example. A further exemplary embodiment for structuring involves the configuration of a nub structure, e.g. with upwardly directed nubs of few 100 μm height and few millimeters diameter as well as a spacing between the nubs of few millimeters.

**[0026]** The attainable values are demonstrated with reference to an exemplary embodiment. Originating from a steel with the analysis

C = 0.06 %
Mn = 15.5 %
Al = 2.0 %
Si = 2.6 %
$H_2$ = 4 ppm,

a hot strip has been manufactured at a thickness of 2.5 mm.

**[0027]** The tensile specimen lying in rolling direction resulted in a tensile strength of 1046 MPa and an elongation (A80) of 35 %. Depending on the deformation degree and heat treatment, the tensile strength may be increased up to above 1100 MPa and the elongation (A80) above 40 %.

**[0028]** A second example shows the possibility to shift the strength and ductility characteristics relative to one another through an increase in carbon content at almost same Mn content.

**[0029]** Steel of this exemplary embodiment has the following contents:

C = 0.7 %

Mn = 15 %

Al = 2.5 %

Si = 2.5 %

$H_2$ = 3 ppm

**[0030]** The cold strip of 1.0 mm made from this steel is annealed for recrystallization under inert gas at 1050 °C and a retention time of 15 minutes. The tensile strength is lowered to 817 MPa, while the A80 elongation rose to 60 %. This means that despite the low Mn content as a consequence of the higher carbon addition, the steel has been shifted more into the range with TWIP characteristics.

**[0031]** A further example shows the results with high Mn content and low carbon content. The contents amounted to

C = 0.041 %

Mn = 25 %

Al = 3.4 %

Si = 2.54 %

$H_2$ = 4 ppm

**[0032]** Following a comparable heat treatment, as described above, the tensile strength was on average 632 MPa and the A80 elongation 57 %. Also this example clearly demonstrates the substantial increase in elongation with high Mn contents at the expense of strength however, so long as the carbon content is low.

**[0033]** In summary, the three examples show the broad variation with respect to strength and elongation, with the Mn and C contents playing a key role. The analysis impact is compounded by treatments of the hot strip in the form of

annealing and/or combined cold forming (e.g. rolling, stretching, deep drawing) and intermediate annealing or final annealing.